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- ☒ 12 sheets of formal drawings
- ☒ Certified copy of a Japanese application, Serial No. 11-278683, filed September 30, 1999, the right of priority of which is claimed under 35 U.S.C. 119
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SURFACE ACOUSTIC WAVE DEVICE AND METHOD FOR PRODUCING THE SAME

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The present invention relates to a surface acoustic wave device and a method for producing the same.

2. Description of the Related Art

10 A surface acoustic wave device is used, for example, in a high frequency circuit of cellular phones. Fig. 12 shows a SAW filter 1 in a plan view as an example of a conventional surface acoustic wave device (hereinafter, referred to also as a SAW device). The SAW filter 1 includes a piezoelectric substrate 2 and a pair of interdigital transducers 3a and 3b
15 (hereinafter, referred to also as IDT electrodes) formed on the substrate 2. The substrate 2 is formed of LiTaO_3 , LiNbO_3 or the like.

In the SAW filter 1, if the substrate 2 has a pyroelectric property, a change in temperature in an assembly process or a change in temperature when used as a device causes non-uniformity in electric charge distribution on
20 the surface of the substrate 2. As a result, a potential difference is generated between the IDT electrodes 3a and 3b so that discharge occurs between the electrodes. The discharge between the electrodes causes melting and cutting-off of the electrodes, resulting in deterioration or shift of the characteristics of the filter.

25 In order to solve the above problem, the following three methods have been proposed. A first method is to connect the two IDT electrodes by a fine metal electrode (see JP 3-29407A). However, since this metal electrode is fine, the electric connection is easily broken, for example by heat. Thus, this method cannot provide a reliable filter.

30 A second method is to form a thin film having a predetermined resistivity that covers the IDT electrodes (see JP1-106611A, JP10-303681A, and JP11-74750A). However, in the above method, since the IDT electrodes are covered with the thin film, the characteristics for propagation of surface acoustic waves may be deteriorated. In addition, a process for forming the
35 thin film is required.

A third method is to treat the substrate with heat in a reducing gas to reduce the surface resistance, and then to form IDT electrodes (see JP11-

92147A)

However, the SAW filter obtained by the third method has a problem in that insertion loss of high frequency characteristics is increased. It is believed that this is caused by lattice defects generated significantly deep in the substrate when the substrate is treated with heat in a reducing gas, which affects the propagation of the surface acoustic wave energy.

SUMMARY OF THE INVENTION

Therefore, with the foregoing in mind, it is an object of the present invention to provide a surface acoustic wave device in which discharge hardly occurs between the IDT electrodes and that has good characteristics for propagation of surface acoustic waves, and to provide a method for producing the same.

A first surface acoustic wave device of the present invention includes a piezoelectric substrate, a first interdigital transducer and a second interdigital transducer formed on the substrate so that the first and second interdigital transducers are opposed to each other. The substrate includes a doping region that is doped with a substance in at least one form selected from the group consisting of atoms, molecules and clusters in a surface between the first and second interdigital transducers. This substance may be in the form of ions or radicals. This invention is based on the discovery that when the doping region is formed between the electrodes, discharge between the electrodes can be suppressed. While not wishing to be bound by any particular theory, one reason might be that the doping region has a lower resistance than that of the substrate that is not doped. In the above-described SAW device, when a potential difference is generated between the first IDT electrode and the second IDT electrode, electric charges are transferred via the doping region so that the potential difference is eliminated. Therefore, according to the above-described SAW device, discharge between the IDT electrodes can be suppressed. Moreover, in the above-described SAW device, the doping region is formed only in the surface of the substrate. Therefore, the SAW device has good characteristics for propagation of surface acoustic waves.

In the above-described surface acoustic wave device, the depth of the doping region may be not more than 50nm. Most of the surface acoustic waves that propagate on the surface of the SAW device propagate in a region in a depth up to about 1/4 of the wavelength of the surface acoustic wave from

the surface of the substrate. In the case of a SAW device with a 2GHz band using LiNbO_3 , the surface acoustic waves propagate in a region in a depth up to about $0.5\mu\text{m}$ from the surface of the substrate. This embodiment can provide a SAW device having particularly good characteristics for propagation of the surface acoustic waves, because the doping region is sufficiently thin relative to the region for propagation.

In the above-described surface acoustic wave device, it is preferable that the doping region has a lower resistance than that of an inner portion of the substrate.

In the above-described surface acoustic wave device, the sheet resistance of the doping region may be in a range from $10^8\Omega/\square$ to $10^{15}\Omega/\square$. This embodiment particularly can suppress discharge between the IDT electrodes.

In the above-described surface acoustic wave device, the substance may be a substance obtained by ionizing at least one selected from the group consisting of a reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, chromium, tantalum, molybdenum, germanium, and nickel. This embodiment can prevent electric charges from being accumulated on the substrate, because the conductivity in the vicinity of the surface of the substrate becomes high.

In the above-described surface acoustic wave device, the first and second interdigital transducers may be provided with an insulating layer on surfaces thereof. In this specification, "on a surface" includes "in a surface", and forming on a surface includes forming by doping in a surface. This embodiment can prevent the short-circuit of the electrodes caused by conductive particles. Moreover, this embodiment can prevent corrosion of the electrodes, and this effect is particularly large when the electrodes comprise aluminum. Furthermore, when the insulating layer is formed by doping a metal with impurities, the doping of impurities reduces the grain size of crystals on the surface of the electrodes, so that movement of atoms of Al or the like can be inhibited. Therefore, in this case, migration in the electrodes can be suppressed.

In the above-described surface acoustic wave device, the average thickness of the insulating layer may be in a range from 2nm to 500nm, and the resistivity of the insulating layer may be not less than $10^6\Omega\text{ cm}$. An average thickness of the layer of 2nm or more can suppress the short-circuit between the electrodes and corrosion of the electrodes. An average thickness

of the layer of 500nm or less can prevent deterioration of the characteristics of the surface acoustic wave device. Furthermore, a resistivity of the insulating layer of not less than $10^6 \Omega \text{ cm}$ particularly can suppress the short-circuit between the electrodes.

5 In the above-described surface acoustic wave device, the insulating layer may be made of a metal nitride or a metal oxide. This embodiment can prevent not only pyroelectricity breakdown of the electrodes, but also corrosion of the electrodes and the short-circuit between the electrodes.

10 In another aspect of the present invention, a method for producing a surface acoustic wave device includes (a) forming a first interdigital transducer and a second interdigital transducer on a piezoelectric substrate so that the first and second interdigital transducers are opposed to each other; and (b) forming a doping region in a surface of the substrate between the first and second interdigital transducers by doping the surface of the substrate
15 with a substance in at least one form selected from the group consisting of atoms, molecules and clusters before or after the process (a). This substance may be in the form of ions or radicals. This method can provide a surface acoustic wave device in which discharge between the IDT electrodes hardly occurs and that has good characteristics for propagation of surface acoustic
20 waves.

In the above-described method for producing a surface acoustic wave device, the substrate may be doped with the substance in a depth of not more than 50nm from the surface thereof. This embodiment allows the doping region to be formed in a depth of not more than 50nm.

25 In the above-described method for producing a surface acoustic wave device, it is preferable that the doping region has a lower resistance than that of an inner portion of the substrate. In this case, the sheet resistance of the doping region may be in a range from $10^8 \Omega/\square$ to $10^{15} \Omega/\square$.

30 In the above-described method for producing a surface acoustic wave device, the substrate may be doped with the substance in ionized form.

In the above-described method for producing a surface acoustic wave device, the dose of the substance may be in a range from $1 \times 10^{13} \text{ ions/cm}^2$ to $1 \times 10^{17} \text{ ions/cm}^2$. A dose of not less than $1 \times 10^{13} \text{ ions/cm}^2$ can form a doping region having a preferable sheet resistance. A dose of not more than 1×10^{17}
35 ions/cm^2 particularly can suppress the deterioration of the characteristics of the SAW device.

In the above-described method for producing a surface acoustic wave

device, the substrate may be doped with the substance in an energy of 0.01keV to 10keV. This embodiment allows the depth of the doping region to be 50nm or less, and particularly can suppress the deterioration of the characteristics of the SAW device.

In the above-described method for producing a surface acoustic wave device, the substance may be a substance obtained by ionizing at least one selected from the group consisting of a reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, chromium, tantalum, molybdenum, germanium, and nickel.

In the above-described method for producing a surface acoustic wave device, the substrate may be doped with the substance by at least one technique selected from the group consisting of ion implantation, ion doping, plasma doping, laser doping and vapor phase doping. This embodiment can form a doping layer simply and controllably.

The above-described method for producing a surface acoustic wave device further may include (c) forming an insulating layer in surfaces of the first and second interdigital transducers by doping the surfaces of the first and second interdigital transducers with impurities after the process (a). This embodiment can prevent the short-circuit between the electrodes caused by conductive particles.

In the above-described method for producing a surface acoustic wave device, the impurities may be the same substance as said substance, and the process (c) may be performed at the same time as the process (b). This embodiment can form the doping region and the insulating layer at one time of doping.

In the above-described method for producing a surface acoustic wave device, the impurities may be oxygen or nitrogen.

In the above-described method for producing a surface acoustic wave device, the average thickness of the insulating layer may be in a range from 2nm to 500nm, and the resistivity of the insulating layer may be not less than $10^6 \Omega \text{ cm}$.

A second surface acoustic wave device of the present invention includes a piezoelectric substrate, a first interdigital transducer and a second interdigital transducer formed on the substrate so that the first and second interdigital transducers are opposed to each other, wherein the substrate includes a plurality of conductive regions that spaced apart from each other on a surface thereof between the first and second interdigital transducers, and a

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tunnel current flows between the first and second interdigital transducers via the conductive regions.

As described above, the SAW device of the present invention and the method for producing a SAW device of the present invention easily provide a surface acoustic wave device in which discharge between the IDT electrodes hardly occurs and that has good characteristics for SAW propagation. The present invention is useful for various SAW devices such as ladder type or traveling-wave type SAW filters or SAW resonators.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a plan view of an example of a SAW device of the present invention.

Fig. 1B is a cross-sectional view of the example of the SAW device of the present invention.

Fig. 2 is a cross-sectional view of another example of a SAW device of the present invention.

Figs. 3A to 3C are views showing a process sequence of an example of a method for producing a SAW device of the present invention.

Fig. 4 is a schematic view showing an example of a plasma doping apparatus used in a method for producing a SAW device of the present invention.

Fig. 5 is a schematic view showing an example of an ion implanting apparatus used in a method for producing a SAW device of the present invention.

Figs. 6A to 6D are views showing a process sequence of another example of a method for producing a SAW device of the present invention.

Figs. 7A to 7C are views showing a process sequence of yet another example of a method for producing a SAW device of the present invention.

Figs. 8A to 8C are views showing a process sequence of still another example of a method for producing a SAW device of the present invention.

Figs. 9A to 9D are views showing a process sequence of another example of a method for producing a SAW device of the present invention.

Figs. 10A to 10C are views showing a process sequence of yet another example of a method for producing a SAW device of the present invention.

Fig. 11A is a cross-sectional view of yet another example of a SAW device of the present invention.

Fig. 11B is a cross-sectional view of still another example of a SAW device of the present invention.

5 Fig. 12 is a plan view of an example of a conventional SAW device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

10 Embodiment 1

In Embodiment 1, a SAW device of the present invention will be described. Fig. 1A is a plan view of a SAW device 10 of Embodiment 1. Fig. 1B is a cross-sectional view of the SAW device 10 taken along line X-X.

Referring to Figs. 1A and 1B, the SAW device 10 includes a substrate 15 11, a pair of IDT electrodes 12 formed on the substrate 11, and reflectors 13 formed on the substrate 11. The pair of IDT electrodes 12 includes a first IDT electrode 12a and a second IDT electrode 12b. The substrate 11 includes a doping region 11a in a substrate surface 11s between the first IDT electrode 12a and the second IDT electrode 12b and between the IDT electrodes 12 and 20 the reflectors 13. The SAW device 10 includes electric wires or pad electrodes, if necessary. Furthermore, the SAW device of the present invention may include a plurality of sets of IDT electrodes on the substrate.

A substrate having a piezoelectric property and a pyroelectric property can be used as the substrate 11. Specifically, a substrate made of LiTaO_3 or 25 LiNbO_3 can be used. More specifically, a 64° Y-cut X-propagating LiNbO_3 substrate or a 39° Y-cut X-propagating LiTaO_3 substrate can be used.

The doping region 11a in the substrate 11 is doped with a substance in at least one form selected from the group consisting of atoms, molecules and clusters. The substance for doping may be in the form of ions or radicals. 30 The doping region 11a has a lower resistance than that of the inner portion of the substrate. In other words, the doping region 11a has a lower resistance than that of the substrate that is not doped. The resistivity and the depth of the doping region 11a are set to such values that can suppress discharge between the first IDT electrode 12a and the second IDT electrode 12b. 35 Preferably, the depth of the doping region 11a from the substrate surface 11s is 50nm or less, and more preferably is 10nm or less.

The sheet resistance of the substrate surface 11s between the first and

the second IDT electrodes 12a and 12b, namely, the sheet resistance of the doping region 11a, preferably is in the range from $10^8\Omega/\square$ to $10^{15}\Omega/\square$, more preferably in the range from $10^{12}\Omega/\square$ to $10^{14}\Omega/\square$ (The sheet resistance is measured in an electric field of 10^5V/cm or less, which also applies to the following). A sheet resistance of $10^8\Omega/\square$ or more can suppress the deterioration of the characteristics of the SAW device 10 such as insertion loss.

Discharge between the IDT electrodes 12a and 12b depends on the temperature, the rate of temperature change of the substrate 11, the state of the gas in contact with the surface of the substrate 11, and the state of light with which the substrate is irradiated during the production process or in use. Moreover, the discharge depends on the distance between the two adjacent electrodes, the shape of the ends of the electrodes, and the area of the electrodes. Therefore, the sheet resistance of the doping region 11a is adjusted in view of the aforementioned conditions. The sheet resistance can be adjusted by changing the type or the amount of the substance with which the substrate is doped.

The sheet resistance of a LiTaO_3 substrate or a LiNbO_3 substrate is about $10^{15}\Omega/\square$ or more in an average electric field of 10^5V/cm or less when the substrate is not doped. Thus, the sheet resistance of the surface of the doping region 11a has a lower resistance than that of the inner portion of the substrate.

As the substance with which the doping region 11a is doped, for example, a substance obtained by ionizing at least one ion species selected from the group consisting of a reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, chromium, tantalum, molybdenum, germanium, and nickel can be used. As the reducing gas, for example, hydrogen, carbon monoxide, nitrogen monoxide or the like can be used. Among these, it is most preferable to use nitrogen as the ion species, because nitrogen causes only a small level of deterioration of the characteristics for propagation of surface acoustic waves.

When a substrate made of an oxide such as LiTaO_3 or LiNbO_3 is used, it is advantageous to use the reducing gas as the ion species. It is believed that when the reducing gas is used as the ion species, oxygen defects can be formed effectively on the surface of the substrate made of an oxide. More specifically, such oxygen defects act as a donor so that the surface resistance of the doping region 11a can be reduced. Furthermore, when the substrate is made of LiTaO_3 , it also is advantageous to dope the substrate with carbon or

nitrogen. In this case, tantalum carbide or tantalum nitride, which is a compound having a conductivity higher than that of LiTaO_3 , is formed, so that the surface resistance of the doping region 11a is reduced.

It is believed that also when a neutral gas such as Ar or nitrogen, gas having a relatively large mass, or a metal is used as the ion species, lattice defects can be formed in the substrate surface. It is believed that such lattice defects act as a trap center, a donor, or an acceptor, so that the surface resistance of the doping region 11a is reduced.

In the case where doping is performed with accelerated ions, the accelerating energy for doping can be in the range from 0.01keV to 10keV. The dose in this case can be any amount, as long as the sheet resistance as described above is attained. For example, a dose of 1×10^{13} ions/cm² to 1×10^{17} ions/cm² can be used.

Figs. 1A and 1B show the IDT electrodes 12 only schematically, and IDT electrodes 12 for practical use are provided with more branches, for example, 100 to 500 branches. The IDT electrodes are made of Al, an Al alloy or other metals. As an Al alloy, for example, an Al-Cu alloy or an Al-Cu-Si alloy can be used. The IDT electrodes 12 can be formed with a single metal film or a plurality of metal films. The shortest distance between the first IDT electrode 12a and the second IDT electrode 12b depends on the speed of sound as determined by the frequency and the substrate material. For example, the shortest distance therebetween is in the range from 0.01 μm to 100 μm .

The reflectors 13 are formed to suppress leakage of the surface acoustic waves from the IDT electrodes 12. The reflectors are formed in such a manner that the IDT electrodes 12 are interposed between the reflectors. The reflectors can be made of the same material as used for the IDT electrodes 12.

The SAW device 10 can be used as a single device or in connection with a package, which encloses the SAW device. The SAW device 10 can be connected to the package by wire bonding or flip chip bonding.

Figs. 1A and 1B show the SAW device where the doping region 11a is formed only between adjacent electrodes (including the IDT electrodes and the reflectors) on the substrate 11. However, as shown in Fig. 6D, the doping region can be formed in the entire surface of the substrate on the side where the IDT electrodes are formed.

Furthermore, the SAW device of the present invention may include an insulating layer on the surface of the IDT electrodes. Fig. 2 shows an

example of such a SAW device 20 in section. The SAW device 20 is different from the SAW device 10 only in the IDT electrodes and the reflectors, so that duplicate description will be omitted.

5 The SAW device 20 includes IDT electrodes 22 and reflectors 23 formed on the substrate 11. The IDT electrodes 22 include a first IDT electrode 22a and a second IDT electrode 22b. The first IDT electrode 22a and the second IDT electrode 22b are the first IDT electrode 12a and the second IDT electrode 12b provided with an insulating layer 24 on the surfaces thereof, respectively. In other words, the IDT electrodes 22 are provided with
10 the insulating layer 24 on the surfaces thereof. Furthermore, the reflectors 23 are provided with an insulating layer 25 on the surface thereof. The resistivity of the insulating layers 24 and 25 is, for example, $10^6 \Omega \text{ cm}$ or more. The insulating layers 24 and 25 are made of, for example a metal nitride or a metal oxide. For example, aluminum nitride or aluminum oxide can be used
15 for the insulating layers 24 and 25. The thickness of the insulating layers 24 and 25 preferably is 2nm to 500nm, more preferably 2nm to 10nm. The insulating layer 24 can be formed by doping the surface of the IDT electrodes made of a metal with impurities that form an insulator with the metal. Similarly, the insulating layer 25 can be formed by doping the reflectors made
20 of a metal with impurities. Examples of the impurities include nitrogen and oxygen. Doping of the impurities can be performed in the same manner in which the doping region 11a is formed, which will be described in Embodiment 2.

25 The SAW device of Embodiment 1 can be produced in the same manner as described in Embodiment 2.

In the SAW device of Embodiment 1, the doping region 11a is formed in the substrate surface 11s. Therefore, this SAW device can prevent discharge between the electrodes from occurring during and after production. Furthermore, since the doping region 11a is formed only in the surface of the
30 substrate 11, the SAW device has good characteristics for propagation of surface acoustic waves.

Moreover, the SAW device of Embodiment 1 can be miniaturized, because it is unnecessary to form metal electrodes for connection, unlike conventional SAW devices where the IDT electrodes are connected by metal
35 electrodes.

Embodiment 2

In Embodiment 2, a method of the present invention for producing a SAW device will be described. The same components as those described in Embodiment 1 bear the same reference numerals, and duplicate description will be omitted.

5 The method of Embodiment 2 includes (a) forming a first IDT electrode and a second IDT electrode on a piezoelectric substrate in such a manner that the first IDT electrode and the second IDT electrode are opposed to each other. Hereinafter, this process may be referred to as process (a).

10 Furthermore, this method includes (b) forming a doping region in a surface of the substrate by doping the surface of the substrate between the first IDT electrode and the second IDT electrode with a substance in at least one form selected from the group consisting of atoms, molecules and clusters before or after the process (a). Hereinafter, this process may be referred to as process (b). The substance with which the substrate is doped may be in the
15 form of ions or radicals.

Hereinafter, an example of the method of Embodiment 2 will be described with reference to Figs. 3A to 3C. The drawings of the production process described below show only a part of the substrate. In the actual production process, a plurality of devices may be formed in a substrate and
20 the substrate will be divided, if necessary.

In this method, first, as shown in Fig. 3A, a pair of IDT electrodes 12 and reflectors 13 are formed on a substrate 31. A first IDT electrode 12a and a second IDT electrode 12b are opposed to each other. The substrate 31 becomes the substrate 11. The IDT electrodes 12 can be formed by
25 photolitho-etching or lift-off technology.

Thereafter, as shown in Fig. 3B, the doping region 11a is formed in the substrate surface 11s at least between the first IDT electrode 12a and the second IDT electrode 12b and between the IDT electrodes 12 and the reflectors 13. The doping region 11a can be formed by doping the substrate
30 surface 11s with a substance in at least one form selected from the group consisting of atoms, molecules and clusters (hereinafter, the substance may be referred to as an additive substance). Thus, the SAW device 10 provided with the substrate 11 can be produced.

It is preferable to dope the substrate surface 11s with the additive
35 substance in a depth of not more than 50nm (more preferably, not more than 10nm) from the substrate surface 11s. In other words, it is preferable that the depth of the doping region 11a is not more than 50nm. The doping region

11a has a lower resistance than that of the inner portion of the substrate. The sheet resistance of the substrate surface 11s, namely, the doping region 11a, preferably is in the range from $10^8\Omega/\square$ to $10^{15}\Omega/\square$, more preferably in the range from $10^{12}\Omega/\square$ to $10^{14}\Omega/\square$.

5 The additive substance can be used in the form of ions for doping. In this case, the dose of ions can be any amount, as long as the sheet resistance as described above is attained. For example, a dose of 1×10^{13} ions/cm² to 1×10^{17} ions/cm² can be used. Furthermore, in the case where doping is performed while accelerating ions, the accelerating energy for the doping can
10 be in the range from 0.01keV to 10keV. In particular, in the case where nitrogen ions are used for doping, it is preferable that doping is performed at an accelerating energy of 0.05keV to 0.3keV.

 As the additive substance, for example, a substance obtained by ionizing at least one ion species selected from the group consisting of a
15 reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, Cr, Ta, Mo, Ge, and Ni can be used. As the reducing gas, for example, hydrogen, carbon monoxide, nitrogen monoxide or the like can be used. As atoms with which the substrate is doped, nitrogen radicals or oxygen radicals can be used.

20 When a substrate made of an oxide such as LiTaO₃ or LiNbO₃ is used, it is advantageous to use the reducing gas as the ion species. Furthermore, it also is advantageous to use a neutral gas such as Ar or nitrogen, gas having a relatively large mass, or metal ions.

 The doping of the additive substance can be performed by at least one
25 technique selected from the group consisting of ion implantation, ion doping, plasma doping, laser doping and vapor phase doping. In the ion implantation technique, doping is performed by accelerating ions generated in plasma and separating the ions by mass. In the ion doping technique, doping is performed by accelerating ions generated in plasma without separating the
30 ions by mass. In the plasma doping, doping is performed by exposing the substrate to plasma. In the laser doping technique, doping is performed by irradiating the surface of the substrate with a laser while exposing the substrate to a gas comprising atoms with which the substrate is to be doped. In the vapor phase doping technique, doping is performed by exposing the
35 substrate to a gas comprising atoms with which the substrate is to be doped and then treating the substrate with heat. Among these, plasma doping is preferable in that it is a low-temperature and low energy process, and

therefore a shallow doping region can be formed easily.

Fig. 4 schematically shows the structure of an example of a plasma doping apparatus. The doping apparatus 40 includes a chamber 41 and a substrate stage 42 placed in the chamber 41. A tube for gas supply (not shown) and a tube for exhaustion (not shown) are connected to the chamber 41. Plasma 43 is formed immediately above the substrate stage 42. A substrate 44 on the substrate stage 42 is exposed to the plasma 43 and doped with radicals or ions in the plasma 43. The plasma 43 is formed by RF electrodes (not shown) provided in the chamber 41.

Fig. 5 schematically shows the structure of an example of an ion implanting apparatus. The ion implanting apparatus 50 includes a chamber 51, a mass separator 52 connected to the chamber 51 and a substrate stage 53. A tube for gas supply (not shown) and a tube for exhaustion (not shown) are connected to the chamber 51. Outside the chamber 51, there is an extracted electrode 54 for ions. The chamber 51, the mass separator 52 and the substrate stage 53 are placed substantially under vacuum. The substrate stage 53 is movable. A substrate 56 is placed on the substrate stage 53. Plasma 55 is formed in the chamber 51. Ions generated in the plasma 55 are extracted from the chamber 51 by the extracted electrode 54, accelerated by a pre-accelerator (not shown), separated by the mass separator 52, and accelerated or decelerated by post-accelerator (not shown), if necessary, and then implanted on the substrate 56. The plasma 55 is formed by RF electrodes provided in the chamber 51.

The SAW device 10 can be mounted in the manner shown in Fig. 3C. In the mounting process, first, the substrate 11 is cut into individual elements, and then an element is fixed to a mounting substrate 33 with a resin 32. Then, wire bonding is performed using a bonding wire 34, and seam welding is performed in a nitrogen atmosphere. In this mounting process, the substrate 11 is heated. However, discharge can be prevented because the substrate 11 is provided with the doping region 11a.

In the above method, when the process (b) is performed before the process (a), the doping region may be etched during a process for forming the IDT electrodes 12 (e.g., dry etching). For this reason, in this case, the conditions for the process for forming the IDT electrodes are restricted. On the other hand, when the process (b) is performed after the process (a), such restrictions can be eliminated.

When the process (b) is performed after the process (a), there is an

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advantage in that equipment or material can be shared with an apparatus used in another process. Examples of the apparatus used in another process include a sputtering cleaning apparatus, a dry etching apparatus, and a resist ashing apparatus. Examples of the equipment that can be shared include a chamber, an ionizer, an exhausting apparatus and a gas tube. In particular, when the substrate is doped with ions by a plasma doping technique, doping of the ions can be performed using a dry etching apparatus. In this case, a dry etching process and the plasma doping process can be performed successively in the same chamber or different chambers. In this manner, the SAW device can be produced with good production yield and reliability by performing the process (b) after process (a).

When the SAW device 20 described in Embodiment 1 is produced, the method of the present invention may include a process for forming the insulating layers 24 and 25 by doping the surfaces of the IDT electrodes 12 and the reflectors 13 with impurities after the process (a). Hereinafter, this process may be referred to as process (c).

The insulating layers 24 and 25 can be formed after removing a resist on the electrodes. More specifically, the insulating layers 24 and 25 can be formed before the process (b), at the same time as the process (b), or after the process (b).

When the impurities in the process (c) are the same substance as the additive substance in the process (b), the processes (b) and (c) can be performed at the same time by one doping process. More specifically, when the IDT electrodes 12 and the reflectors 13 are made of a metal comprising Al, it is preferable to dope the substrate 31, the IDT electrodes 12 and the reflectors 13 with nitrogen or oxygen. In this case, the insulating layers are formed most efficiently by using nitrogen radicals and oxygen radicals for doping.

The method of Embodiment 2 can produce a SAW device in which discharge hardly occurs between the IDT electrodes and that has good characteristics for propagation of surface acoustic waves. Moreover, the method of Embodiment 2 can suppress discharge during production processes, so that the SAW device can be produced in good yield.

35 Examples

Hereinafter, the present invention will be described in detail by way of examples. Examples 1 to 4 are examples that can be carried out, and

Example 5 is an example that was actually carried out. In the SAW devices in the following examples, a reflector is not formed. However, a reflector can be formed.

Example 1

In Example 1, an example of a method for producing a SAW device of the present invention will be described. Figs. 6A to 6D show a production process sequence of Example 1.

First, as shown in Fig. 6A, a substrate 61 made of LiTaO_3 is prepared, and the surface thereof is washed. Then, as shown in Fig. 6B, a doping region 61a having a sheet resistance in the range from $10^8 \Omega/\square$ to $10^{15} \Omega/\square$ is formed in the substrate 61. The doping region 61a can be formed by doping the substrate 61 with boron ions by plasma doping. The doping of boron ions can be performed under the conditions of an implantation energy of 700eV and a dose of 1×10^{16} ions/cm².

Then, as shown in Fig. 6C, a metal film 62 (a thickness of 800nm) made of aluminum is formed over the substrate 61 by sputtering.

Then, as shown in Fig. 6D, IDT electrodes 63a and 63b are formed by removing unnecessary portions in the metal film 62. The IDT electrodes are formed in the following manner. First, a resist film (a thickness of 1 μ m) is formed on the metal film 62, and a predetermined pattern is formed by photolithography. Then, unnecessary portions in the metal film 62 are removed by dry-etching using a chlorine-based gas. Finally, the resist film is ashed with oxygen plasma. Thus, the formation of the IDT electrodes is completed.

Thereafter, the mounting of the SAW device is performed. Specifically, first, the substrate 61 is diced and cut into individual elements. Next, die bonding is performed at 180°C with a silicon resin to bond the substrate 61 to a mounting substrate. Then, wire bonding is performed to the IDT electrodes 63a and 63b. Finally, seam welding is performed in a nitrogen atmosphere.

As described above, in the method of Example 1, ions are implanted before the IDT electrodes are formed. According to the SAW device produced by the method of Example 1, discharge between the electrodes can be prevented.

As the ion species, a nitrogen gas comprising 0.1vol% to 5vol% of hydrogen, or a helium gas comprising 0.1vol% to 5vol% of hydrogen may be used. In this case, for example, plasma doping can be performed under the

conditions of an implanting energy of 700eV and a dose of 1×10^{16} ions/cm².

Example 2

In Example 2, another example of a method for producing a SAW device of the present invention will be described. Figs. 7A to 7C show a production process sequence of Example 2.

First, as shown in Fig. 7A, a substrate 71 made of LiTaO₃ is prepared, and the surface thereof is washed.

Then, as shown in Fig. 7B, IDT electrodes 73 including IDT electrodes 73a and 73b are formed. The IDT electrodes are formed in the following manner. First, a metal film (a thickness of 200nm) made of aluminum is formed on a substrate 71, and a resist film (a thickness of 1μm) having a predetermined pattern is formed on the metal film. Then, unnecessary portions in the metal film are removed by dry-etching using a chlorine-based gas. Finally, the resist film is ashed with oxygen plasma. Thus, the formation of the IDT electrodes is completed.

Then, as shown in Fig. 7C, an insulating layer 74 is formed on the IDT electrodes 73a and 73b. At the same time, a doping region 71a having a sheet resistance in the range from $10^8\Omega/\square$ to $10^{15}\Omega/\square$ is formed in a substrate surface 71s between the IDT electrodes 73a and 73b. The insulating layer 74 and the doping region 71a can be formed by doping the substrate 71 with oxygen ions by plasma doping. The doping of oxygen ions can be performed under the conditions of an implantation energy of 5000eV and a dose of 1×10^{17} ions/cm².

Finally, the SAW device is mounted on a mounting substrate in the same manner as in Example 1.

As described above, in the method of Example 2, ions are implanted after the IDT electrodes are formed and the resist film is removed. According to the SAW device produced by the method of Example 2, discharge between the electrodes can be prevented. Moreover, by forming the insulating layer on the surfaces of the electrodes, the method of Example 2 can suppress a short-circuit generated by conductive particles adhering during the production process. Furthermore, according to the SAW device produced by the method of Example 2, corrosion of the electrodes and stress migration can be suppressed.

Example 3

In Example 3, another example of a method for producing a SAW device of the present invention will be described. Figs. 8A to 8C show a

production process sequence of Example 3.

First, as shown in Fig. 8A, a substrate 81 made of LiTaO_3 is prepared, and the surface thereof is washed.

Then, as shown in Fig. 8B, IDT electrodes 83 including IDT electrodes 83a and 83b are formed. The IDT electrodes are formed in the same manner as in Example 2.

Then, as shown in Fig. 8C, a doping region 81a having a sheet resistance in the range from $10^8 \Omega/\square$ to $10^{15} \Omega/\square$ is formed in a substrate surface 81s between the IDS electrodes 83a and 83b. The doping region 81a can be formed by doping the substrate 81 with boron ions by plasma doping. The doping of boron ions can be performed under the conditions of an implantation energy of 700eV and a dose of 1×10^{16} ions/cm². When the boron ions are implanted, the boron ions are implanted also in the IDT electrodes. However, this does not affect the electric characteristics of the SAW device.

Finally, the SAW device is mounted on a mounting substrate in the same manner as in Example 1.

As described above, in the method of Example 3, ions are implanted after the IDT electrodes are formed. According to the SAW device produced by the method of Example 3, discharge between the electrodes can be prevented.

As the ion species, a nitrogen gas comprising 0.1vol% to 5vol% of hydrogen, or a helium gas comprising 0.1vol% to 5vol% of hydrogen may be used. In this case, for example, plasma doping can be performed under the conditions of an implanting energy of 700eV and a dose of 1×10^{16} ions/cm².

Example 4

In Example 4, another example of a method for producing a SAW device of the present invention will be described. Figs. 9A to 9D show a production process sequence of Example 4.

First, as shown in Fig. 9A, a substrate 91 made of LiTaO_3 is prepared, and the surface thereof is washed.

Then, as shown in Fig. 9B, IDT electrodes 93 including IDT electrodes 93a and 93b are formed. The IDT electrodes are formed in the same manner as in Example 2.

Then, as shown in Fig. 9C, an insulating layer 94 is formed on the surfaces of the IDT electrodes 93a and 93b. At the same time, a doping region 91a is formed in a substrate surface 91s between the IDS electrodes

93a and 93b. The insulating layer 94 and the doping region 91a can be formed by plasma-doping of oxygen ions. The doping of oxygen ions can be performed under the conditions of implantation energy: 5000eV and dose: 1×10^{17} ions/cm².

Then, as shown in Fig. 9D, the doping region 91a is doped with boron ions by plasma-doping, so that a doping region 91b having a lower resistance than that of the doping region 91a is formed. The sheet resistance of the doping region 91b is in the range from $10^8 \Omega/\square$ to $10^{15} \Omega/\square$. The doping of boron ions can be performed under the conditions of an implantation energy of 700eV and a dose of 1×10^{16} ions/cm².

Finally, the SAW device is mounted on a mounting substrate in the same manner as in Example 1.

As described above, in the method of Example 4, the same effects provided by the method of Example 2 can be obtained. Moreover, the method of Example 4 allows the sheet resistance of the doping region 91b to be controlled easily.

Example 5

In Example 5, an example of a SAW device actually produced by the method of the present invention will be described. Figs. 10A to 10C show a production process sequence of the method of Example 5.

First, as shown in Fig. 10A, a substrate 101 made of LiTaO₃ was prepared, and the surface thereof was washed.

Then, as shown in Fig. 10B, IDT electrodes 103 including IDT electrodes 103a and 103b were formed. The IDT electrodes were formed in the following manner. First, a metal film (a thickness of 200nm) made of an Al-Cu alloy (Al: Cu = 99.5: 0.5) was formed on the substrate 101, and a resist film (a thickness of 1.5μm) having a predetermined pattern was formed on the metal film. As the resist film, a positive type resist was used. Next, unnecessary portions in the metal film were removed by dry-etching with a mixed gas of BCl₃ and Cl₂. Finally, the resist film was ashed with oxygen plasma, and thus the IDT electrodes were formed.

Then, as shown in Fig. 10C, a doping region 101a was formed in a substrate surface 101s between the IDT electrodes 103a and 103b. The doping region 101a can be formed by ICP plasma-doping of nitrogen ions. In this case, three types of SAW devices were formed under varied doping conditions. These three types of SAW devices were subjected to a heating test and evaluation of RF characteristics. In addition, the same tests were

conducted with respect to a SAW device that was not doped with nitrogen ions as a comparative example. Table 1 shows the doping conditions and the results of the tests with respect to the above samples.

5

Table 1

		Sample 1	Sample 2	Sample 3	Comparative Ex.
Doping condition	ICP power (W)	300	300	300	-
	Substrate bias power (W)	250	100	100	-
	Vacuum degree (Pa)	2	2	2	-
	Doping time (sec.)	120	120	120	-
Heating test results		7	1	2	100
Loss	Δ Loss (db)	0.13	1.03	-0.01	0

10 The heating test was performed by heating 100 devices of each type of sample to 50°C with a hot plate and measuring the number of devices that was damaged by discharge. In Table 1, the number of devices that was damaged of the 100 devices is shown. As the RF characteristics, the mean frequency and the frequency band were measured using a network analyzer.

15 As shown in Table 1, in the samples 1 to 3 of the present invention, pyroelectric breakdown due to heating was suppressed, compared to the comparative samples. In addition, in the sample 3 of the samples 1 to 3, there was essentially no loss.

Example 6

20 Hereinafter, two examples of other SAW devices to prevent piezoelectric breakdown will be described. Fig. 11A is a cross-sectional view of a SAW device 200 of a first example. Fig. 11B is a cross sectional view of a SAW device 210 of a second example.

25 The SAW device 200 includes a substrate 201 made of piezoelectric material and IDT electrodes 202 formed on the substrate 201. The IDT electrodes 202 include pairs of IDT electrodes 202a and 202b that are opposed to each other. The IDT electrodes 202 are the same as the IDT electrodes 12 described in Embodiment 1.

30 In the SAW device 200, a plurality of dotted metals 203 are formed on a substrate surface at least between the IDT electrodes 202a and 202b. The metals 203 are separated by a distance that allows a tunnel current to flow between the adjacent metals 203. More specifically, the metals 203 are

formed on the substrate at a density of 10 metals / μm^2 or more. The metals can be formed, for example by performing a sensitizing treatment and an activating treatment, which are pre-treatments of electroless plating. More specifically, as the sensitizing treatment, the substrate 201 is treated with a treatment aqueous solution (SnCl_2 : 10g /l, HCl : 40ml/l, 323K). Furthermore, as the activating treatment, the substrate 201 is treated with a treatment aqueous solution (PdCl_2 : 0.2g /l, HCl : 20ml/l, 323K). Thus, dotted metals made of palladium can be formed.

In the SAW device 200, when a high voltage is applied across the electrodes, a tunnel current flows via the metals 203, so that discharge between the electrodes can be prevented. Therefore, according to the SAW device 200, discharge breakdown can be prevented during and after the production process. Furthermore, since the metals 203 are insulated, the characteristics of the device are not adversely affected. Furthermore, the SAW device 200 is not affected by environmental changes such as repetition stress and has high reliability.

The dotted metals 203 can be formed by other methods such as utilizing an early state (island-shaped metal) in metal deposition.

The SAW device 210 includes a substrate 211 made of piezoelectric material and IDT electrodes 212 formed on the substrate 211. The IDT electrodes 212 are the same as the IDT electrodes 12 described in Embodiment 1.

The substrate 211 is provided with doping regions 211a (Fig. 11B) formed in stripes. The doping regions may be formed in a mesh. The doping region 211a is formed by doping the substrate with a substance in at least one form selected from the group consisting of atoms, molecules and clusters.

In the SAW device 210, when a high voltage is applied across the electrodes, a tunnel current flows via the doping regions 211a, so that discharge between the electrodes can be prevented. Therefore, according to the SAW device 210, the same effects provided by the SAW device 200 can be obtained. Furthermore, since the doping regions 211a are formed in stripes in the SAW device 210, the direct current resistance is low and the high frequency resistance is high. For this reason, discharge between the electrodes can be prevented, and the same characteristics of a regular SAW device can be obtained.

The invention may be embodied in other forms without departing from

the spirit or essential characteristics thereof. The embodiments disclosed in this application are to be considered in all respects as illustrative and not limiting. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes which come within
5 the meaning and range of equivalency of the claims are intended to be embraced therein.

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WHAT IS CLAIMED IS:

1. A surface acoustic wave device comprising a piezoelectric substrate, a first interdigital transducer and a second interdigital transducer formed on the substrate so that the first and second interdigital transducers are opposed to each other,
wherein the substrate includes a doping region that is doped with a substance in at least one form selected from the group consisting of atoms, molecules and clusters in a surface between the first and second interdigital transducers.
2. The surface acoustic wave device according to claim 1, wherein a depth of the doping region is not more than 50nm.
3. The surface acoustic wave device according to claim 1, wherein the doping region has a lower resistance than that of an inner portion of the substrate.
4. The surface acoustic wave device according to claim 3, wherein a sheet resistance of the doping region is in a range from $10^8 \Omega/\square$ to $10^{15} \Omega/\square$.
5. The surface acoustic wave device according to claim 1, wherein the substance is a substance obtained by ionizing at least one selected from the group consisting of a reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, chromium, tantalum, molybdenum, germanium, and nickel.
6. The surface acoustic wave device according to claim 1, wherein the first and second interdigital transducers are provided with an insulating layer on surfaces thereof.
7. The surface acoustic wave device according to claim 6, wherein an average thickness of the insulating layer is in a range from 2nm to 500nm, and a resistivity of the insulating layer is not less than $10^6 \Omega \text{ cm}$.
8. The surface acoustic wave device according to claim 6, wherein the insulating layer is made of a metal nitride or a metal oxide.

9. A method for producing a surface acoustic wave device comprising:
(a) forming a first interdigital transducer and a second interdigital transducer on a piezoelectric substrate so that the first and second interdigital transducers are opposed to each other; and
5 (b) forming a doping region in a surface between the first and second interdigital transducers by doping the surface of the substrate with a substance in at least one form selected from the group consisting of atoms, molecules and clusters before or after the process (a).

10 10. The method for producing a surface acoustic wave device according to claim 9, wherein the substrate is doped with the substance in a depth of not more than 50nm from the surface of the substrate.

11. The method for producing a surface acoustic wave device according to
15 claim 9, wherein the doping region has a lower resistance than that of an inner portion of the substrate.

12. The method for producing a surface acoustic wave device according to
20 claim 11, wherein a sheet resistance of the doping region is in a range from $10^8\Omega/\square$ to $10^{15}\Omega/\square$.

13. The method for producing a surface acoustic wave device according to claim 9, wherein the substrate is doped with the substance in ionized form.

25 14. The method for producing a surface acoustic wave device according to claim 13, wherein a dose of the substance is in a range from 1×10^{13} ions/cm² to 1×10^{17} ions/cm².

15. The method for producing a surface acoustic wave device according to
30 claim 13, wherein the substrate is doped with the substance at an energy of 0.01keV to 10keV.

16. The method for producing a surface acoustic wave device according to
35 claim 13, wherein the substance is a substance obtained by ionizing at least one selected from the group consisting of a reducing gas, silane, nitrogen, oxygen, argon, silicon, arsenic, boron, phosphorus, tin, indium, chromium, tantalum, molybdenum, germanium, and nickel.

17. The method for producing a surface acoustic wave device according to claim 9, wherein the substrate is doped with the substance by at least one technique selected from the group consisting of ion implantation, ion doping, plasma doping, laser doping and vapor phase doping.

18. The method for producing a surface acoustic wave device according to claim 9, further comprising (c) forming an insulating layer in surfaces of the first and second interdigital transducers by doping the surfaces of the first and second interdigital transducers with impurities after the process (a).

19. The method for producing a surface acoustic wave device according to claim 18, wherein the impurities are the same substance as said substance, and the process (c) is performed at the same time as the process (b).

20. The method for producing a surface acoustic wave device according to claim 18, wherein the impurities are oxygen or nitrogen.

21. The method for producing a surface acoustic wave device according to claim 18, wherein an average thickness of the insulating layer is in a range from 2nm to 500nm, and a resistivity of the insulating layer is not less than $10^6 \Omega \text{ cm}$.

22. A surface acoustic wave device comprising a piezoelectric substrate, a first interdigital transducer and a second interdigital transducer formed on the substrate so that the first and second interdigital transducers are opposed to each other,

wherein the substrate includes a plurality of conductive regions spaced apart from each other on a surface thereof between the first and second interdigital transducers, and a tunnel current flows between the first and second interdigital transducers via the conductive regions.

ABSTRACT OF THE DISCLOSURE

5 A surface acoustic wave device includes a piezoelectric substrate, a first interdigital transducer and a second interdigital transducer formed on the substrate so that the first and second interdigital transducers are opposed to each other. The substrate includes a doping region that is doped with a substance in at least one form selected from the group consisting of atoms, molecules and clusters in a surface between the first and second interdigital transducers.

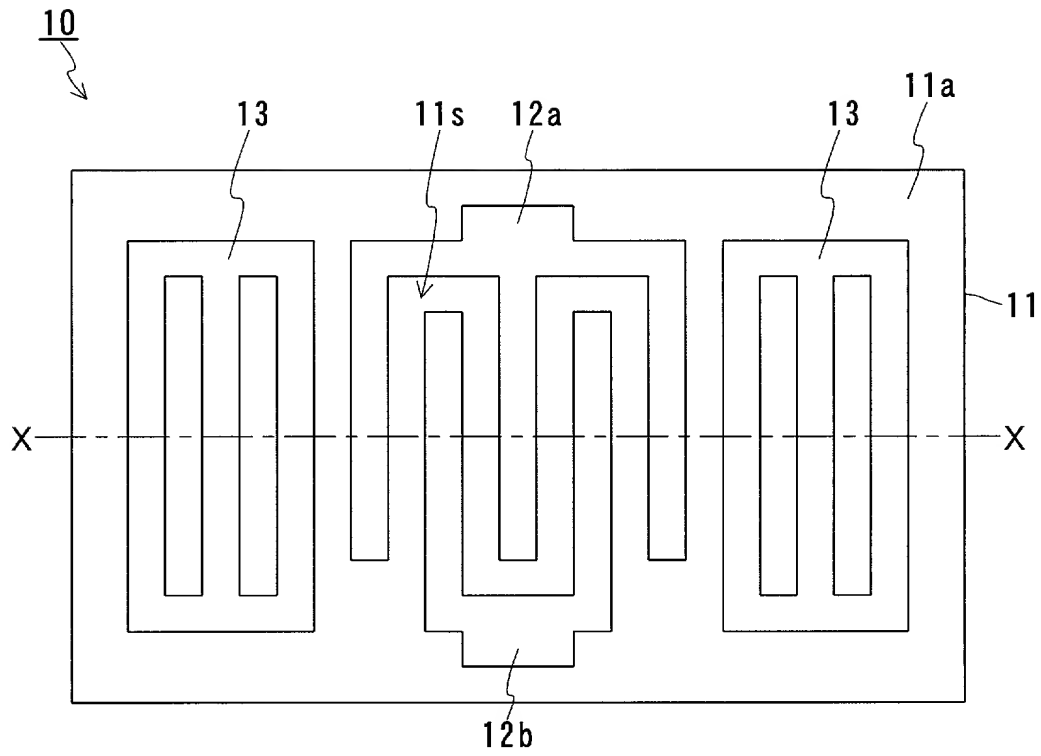


Fig. 1A

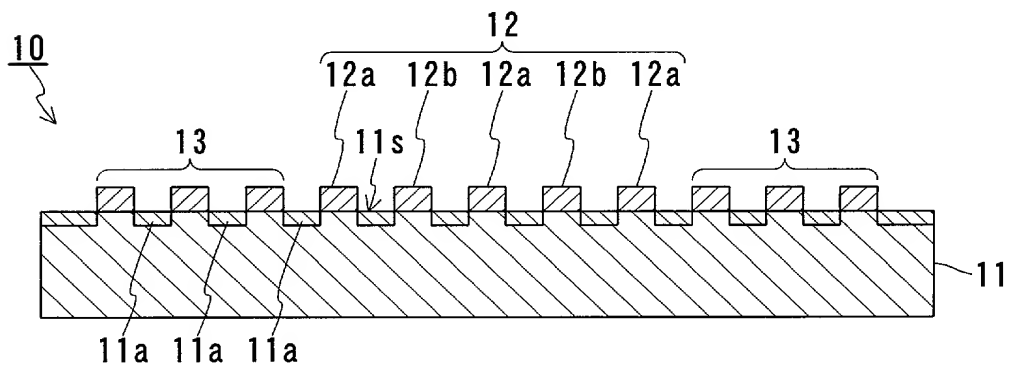


Fig. 1B

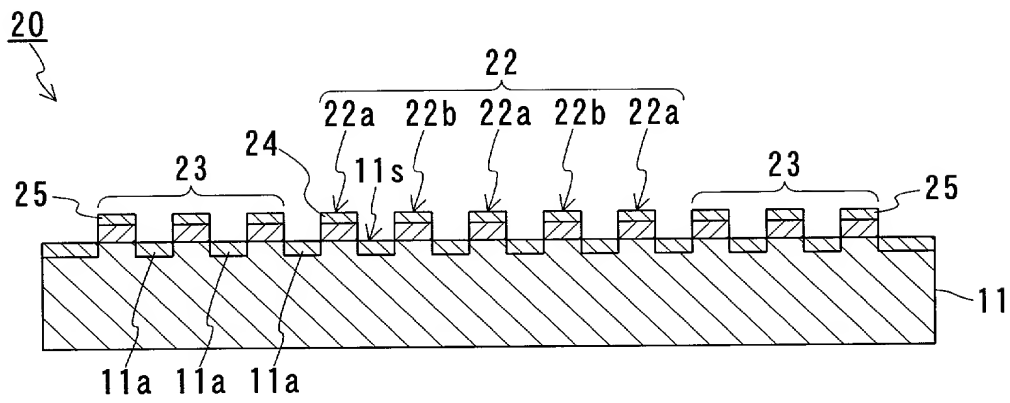
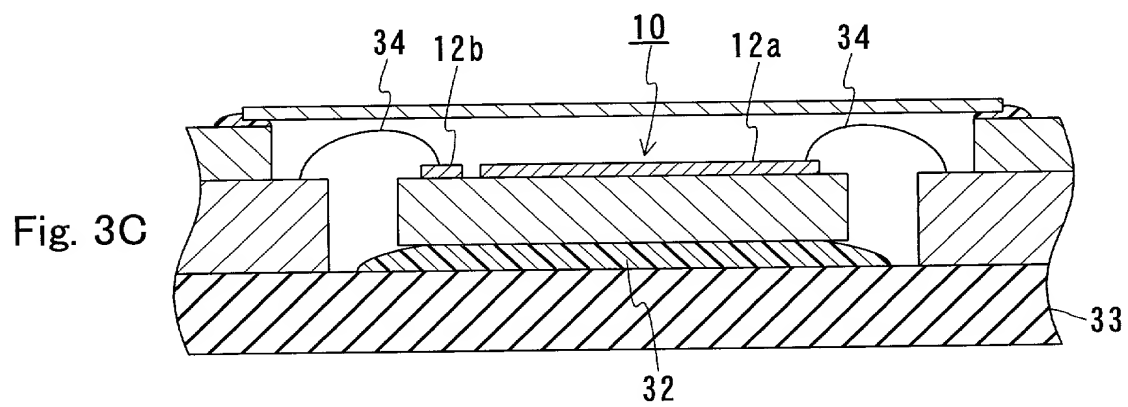
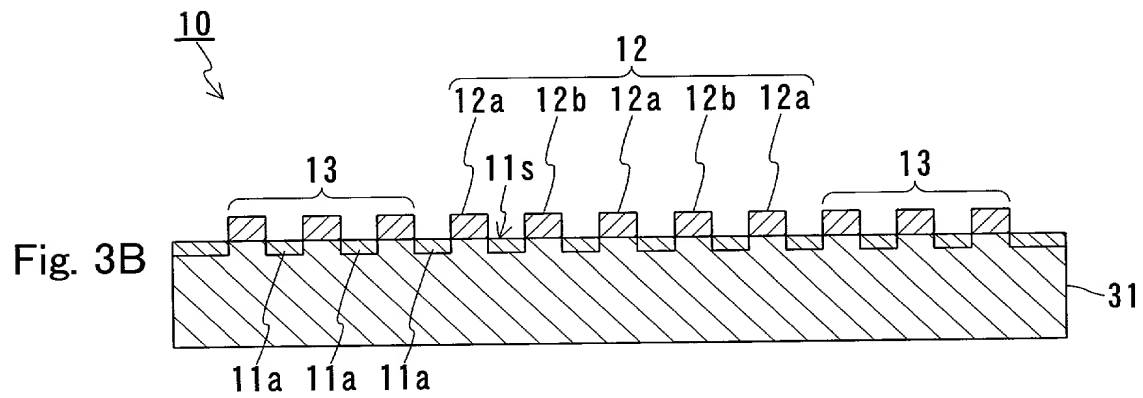
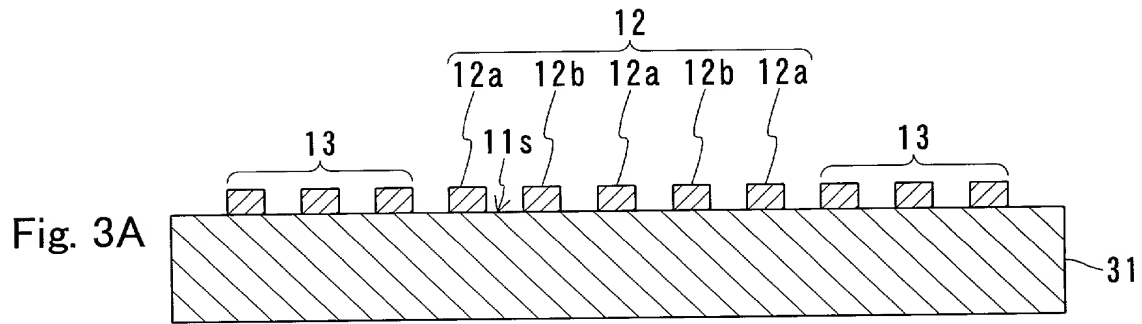


Fig. 2



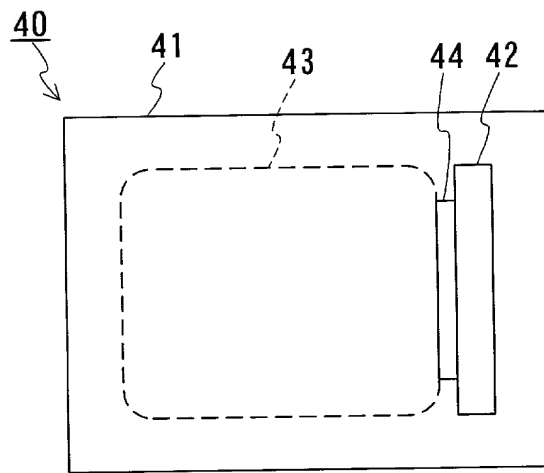


Fig. 4

Fig. 6A

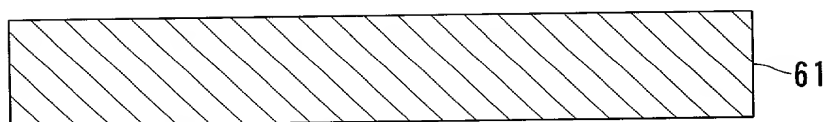


Fig. 6B

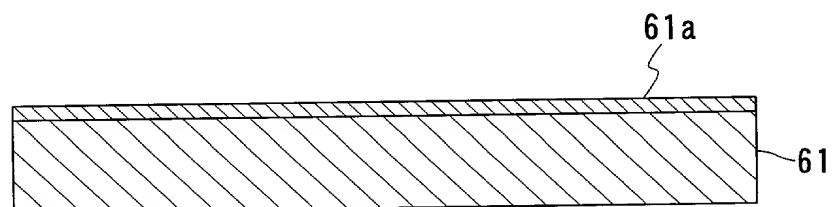


Fig. 6C

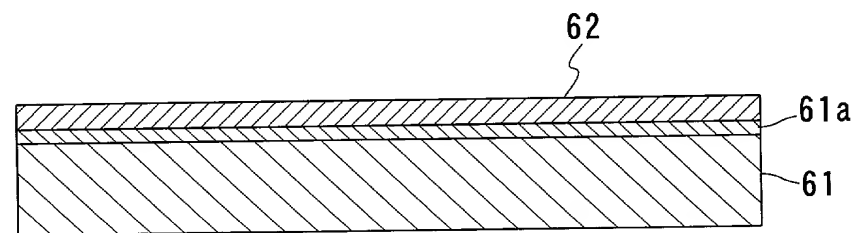


Fig. 6D

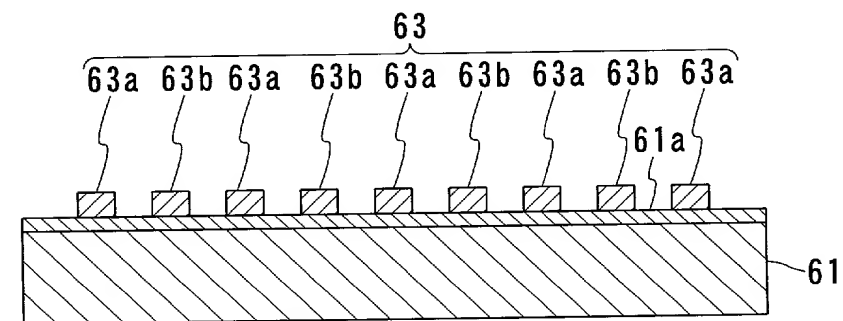


Fig. 8A



Fig. 8B

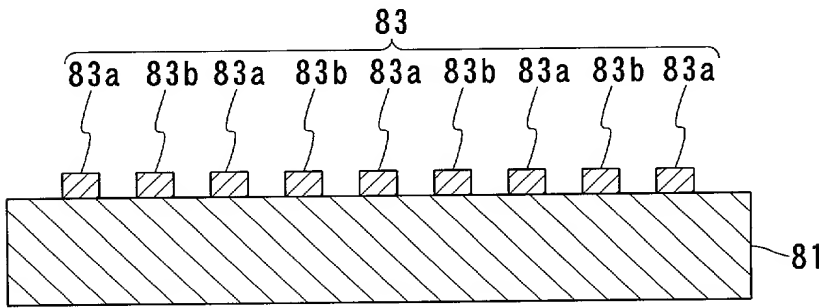


Fig. 8C

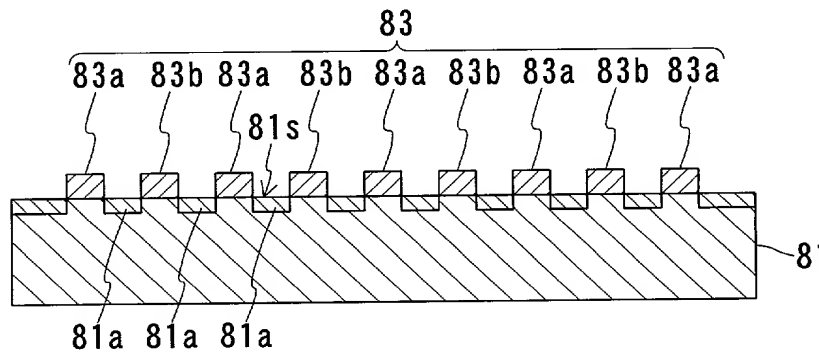


Fig. 10A

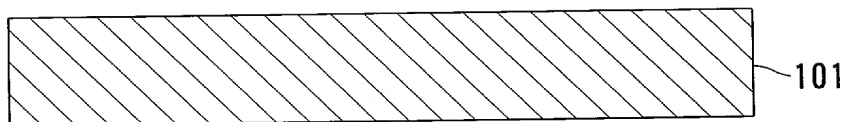


Fig. 10B

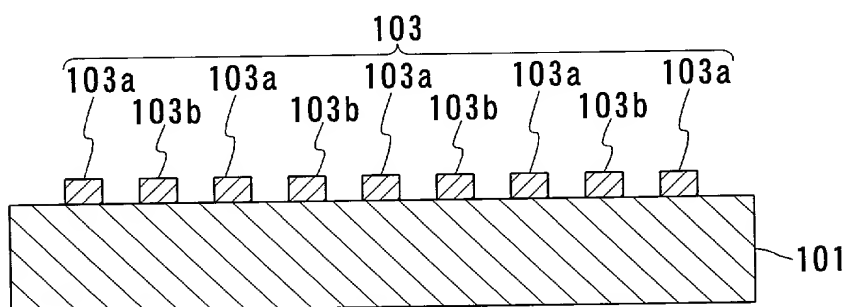
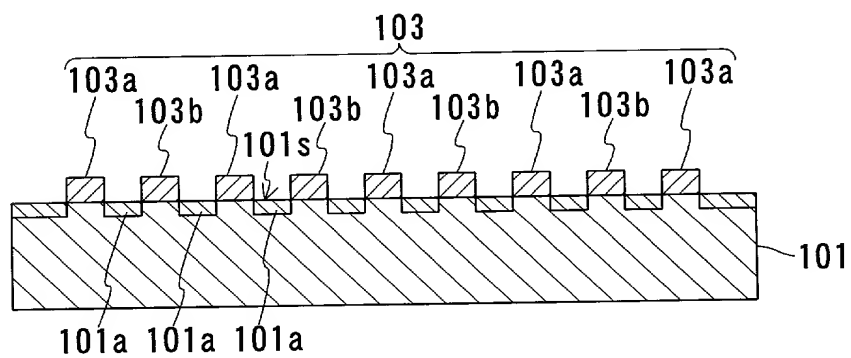


Fig. 10C



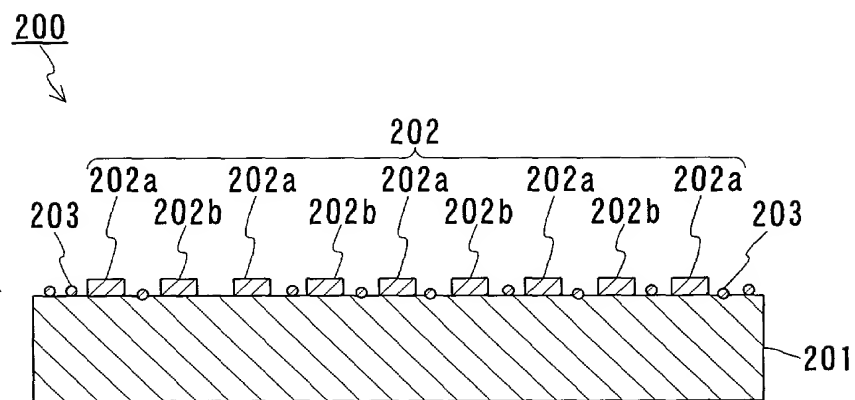
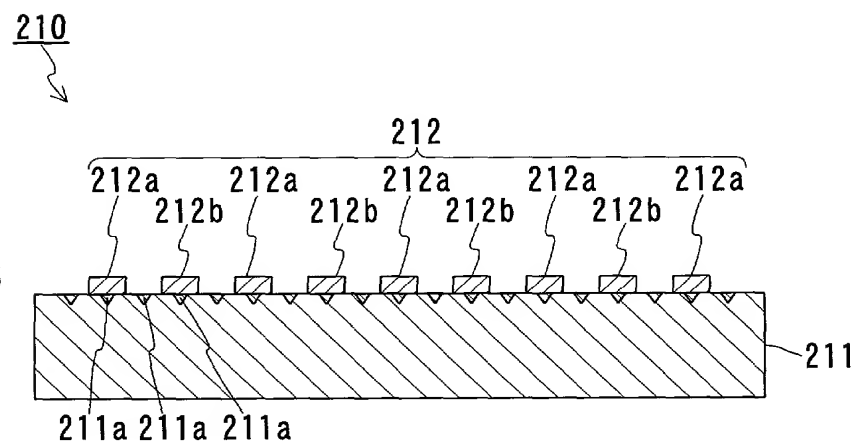


Fig. 11B



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99																																																																																																																																																												
0	00000000	00000001	00000010	00000011	00000100	00000101	00000110	00000111	00001000	00001001	00001010	00001011	00001100	00001101	00001110	00001111	00010000	00010001	00010010	00010011	00010100	00010101	00010110	00010111	00011000	00011001	00011010	00011011	00011100	00011101	00011110	00011111	00100000	00100001	00100010	00100011	00100100	00100101	00100110	00100111	00101000	00101001	00101010	00101011	00101100	00101101	00101110	00101111	00110000	00110001	00110010	00110011	00110100	00110101	00110110	00110111	00111000	00111001	00111010	00111011	00111100	00111101	00111110	00111111	01000000	01000001	01000010	01000011	01000100	01000101	01000110	01000111	01001000	01001001	01001010	01001011	01001100	01001101	01001110	01001111	01010000	01010001	01010010	01010011	01010100	01010101	01010110	01010111	01011000	01011001	01011010	01011011	01011100	01011101	01011110	01011111	01100000	01100001	01100010	01100011	01100100	01100101	01100110	01100111	01101000	01101001	01101010	01101011	01101100	01101101	01101110	01101111	01110000	01110001	01110010	01110011	01110100	01110101	01110110	01110111	01111000	01111001	01111010	01111011	01111100	01111101	01111110	01111111	10000000	10000001	10000010	10000011	10000100	10000101	10000110	10000111	10001000	10001001	10001010	10001011	10001100	10001101	10001110	10001111	10010000	10010001	10010010	10010011	10010100	10010101	10010110	10010111	10011000	10011001	10011010	10011011	10011100	10011101	10011110	10011111	10100000	10100001	10100010	10100011	10100100	10100101	10100110	10100111	10101000	10101001	10101010	10101011	10101100	10101101	10101110	10101111	10110000	10110001	10110010	10110011	10110100	10110101	10110110	10110111	10111000	10111001	10111010	10111011	10111100	10111101	10111110	10111111	11000000	11000001	11000010	11000011	11000100	11000101	11000110	11000111	11001000	11001001	11001010	11001011	11001100	11001101	11001110	11001111	11010000	11010001	11010010	11010011	11010100	11010101	11010110	11010111	11011000	11011001	11011010	11011011	11011100	11011101	11011110	11011111	11100000	11100001	11100010	11100011	11100100	11100101	11100110	11100111	11101000	11101001	11101010	11101011	11101100	11101101	11101110	11101111	11110000	11110001	11110010	11110011	11110100	11110101	11110110	11110111	11111000	11111001	11111010	11111011	11111100	11111101	11111110	11111111

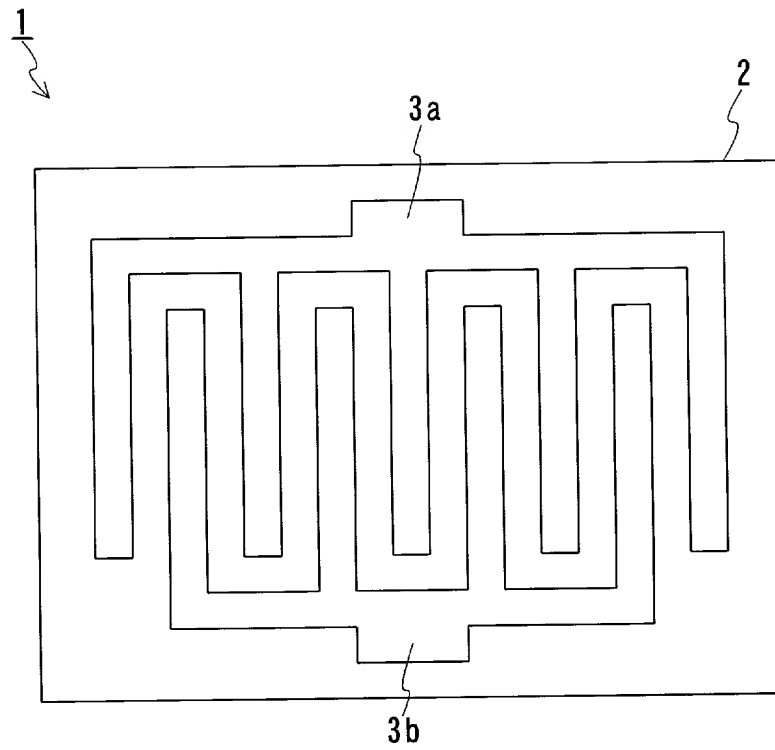


Fig. 12
PRIOR ART

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: SURFACE ACOUSTIC WAVE DEVICE AND METHOD FOR PRODUCING THE SAME

The specification of which

- a. ☒ is attached hereto
b. ☐ was filed on _____ as application serial no. _____ and was amended on _____ (if applicable) (in the case of a PCT-filed application) described and claimed in international no. _____ filed and as amended on _____ (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

- a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
Japan	11-278683	30 September 1999	
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

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Bogucki, Raymond A.	Reg. No. 17,426	McDonald, Daniel W.	Reg. No. 32,044
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Carlson, Alan G.	Reg. No. 25,959	Nelson, Albin J.	Reg. No. 28,650
Caspers, Philip P.	Reg. No. 33,227	Pauly, Daniel M.	Reg. No. 40,123
Chiapetta, James R.	Reg. No. 39,634	Phillips, John B.	Reg. No. 37,206
Clifford, John A.	Reg. No. 30,247	Plunkett, Theodore	Reg. No. 37,209
Cochran, William W.	Reg. No. 26,652	Pytel, Melissa J.	Reg. No. 41,512
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Daley, Dennis R.	Reg. No. 34,994	Reiland, Earl D.	Reg. No. 25,767
Dalglish, Leslie E.	Reg. No. 40,579	Rittmaster, Ted R.	Reg. No. 32,933
Daulton, Julie R.	Reg. No. 36,414	Schmaltz, David G.	Reg. No. 39,828
DeVries Smith, Katherine M.	Reg. No. 42,157	Schuman, Mark D.	Reg. No. 31,197
DiPietro, Mark J.	Reg. No. 28,707	Schumann, Michael D.	Reg. No. 30,422
Edell, Robert T.	Reg. No. 20,187	Scull, Timothy B.	Reg. No. 42,137
Epp Ryan, Sandra	Reg. No. 39,667	Sebald, Gregory A.	Reg. No. 33,280
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Gorman, Alan G.	Reg. No. 38,472	Sumners, John S.	Reg. No. 24,216
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Gregson, Richard	Reg. No. 41,804	Trembath, Jon R.	Reg. No. 38,344
Gresens, John J.	Reg. No. 33,112	Underhill, Albert L.	Reg. No. 27,403
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Kowalchyk, Katherine M.	Reg. No. 36,848	Xu, Min S.	Reg. No. 39,536
Kubota, Glenn M.	Reg. No. 44,197		
Lacy, Paul E.	Reg. No. 38,946		

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant & Gould P.C. to the contrary.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
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Minneapolis, MN 55402-0903

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim;

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.